Inflation and the Pricing of Carbon Risk in European Equity Markets

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Abstract

This dissertation investigates the relationship between carbon emissions, inflation, and stock returns in European equity markets. Building on the framework of Bolton, Kacperczyk, and Wang (2024), it examines whether inflation amplifies the pricing of carbon-transition risk for firms listed in the STOXX Europe 600 Index. The analysis combines firm-level emissions data (Scope 1, 2, and 3) with macroeconomic inflation measures based on the Euro Area Harmonized Index of Consumer Prices (HICP), distinguishing between energy and core inflation. The study evaluates how emissions interact with inflation in shaping monthly stock returns. The findings reveal that energy-driven inflation significantly affects the valuation of carbon-intensive firms. In particular, the interaction between emissions and energy inflation is negative and statistically significant, indicating that firms with higher emissions experience lower stock returns during periods of rising energy prices. In contrast, the relationship with core inflation is weaker and less consistent. Overall, the study emphasizes the importance of macroeconomic conditions in understanding the financial impact of climate-related risks.

Abstract (Portuguese Version)

Esta dissertação investiga a relação entre emissões de carbono, inflação e retornos acionistas nos mercados acionistas europeus. Com base no enquadramento de Bolton, Kacperczyk e Wang (2024), analisa se a inflação amplifica a forma como o risco de transição carbónica é incorporado nos preços das ações das empresas incluídas no índice STOXX Europe 600. A análise combina dados de emissões ao nível da empresa (Scope 1, 2 e 3) com medidas macroeconómicas de inflação baseadas no Índice Harmonizado de Preços no Consumidor (HICP) da área do euro, distinguindo entre inflação da energia e inflação core. O estudo avalia de que forma as emissões interagem com a inflação na determinação dos retornos acionistas mensais. Os resultados mostram que a inflação impulsionada pelos preços da energia afeta significativamente a valorização das empresas com elevada intensidade carbónica. Em particular, a interação entre emissões e inflação da energia é negativa e estatisticamente significativa, indicando que empresas com maiores níveis de emissões apresentam retornos acionistas mais baixos durante períodos de aumento dos preços da energia. Em contraste, a relação com a inflação core é mais fraca e menos consistente. De forma geral, o estudo enfatiza a importância das condições macroeconómicas na compreensão do impacto financeiro dos riscos relacionados com o clima.

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1. Introduction

This thesis examines the relationship between carbon emissions, inflation, and stock returns in European equity markets. Building on the literature on asset pricing and climate-related financial risk, the analysis replicates the framework of Bolton, Kacperczyk, and Wang (2024) for European listed firms. Financial theory suggests that macroeconomic factors, including inflation, influence asset prices through their effects on cash flows, discount rates, and economic activity. At the same time, recent research has shown that carbon emissions represent an important source of transition risk that may affect firms' valuations and realized returns. This study brings together these two strands of literature by investigating whether inflation interacts with firms' carbon emissions in shaping stock returns.

Understanding how climate-related risks are reflected in financial markets has become increasingly important as governments, regulators, and investors place greater emphasis on the transition toward a low-carbon economy. Firms with higher carbon emissions may face a range of potential costs associated with this transition, including stricter environmental regulation, higher carbon prices, and increased pressure to adopt cleaner technologies. These factors can affect firms' profitability, investment decisions, and long-term growth prospects. As a result, investors may increasingly consider firms' carbon exposure when evaluating expected returns and risks in equity markets.

The empirical analysis focuses on firms in the STOXX Europe 600 Index, which provides broad coverage of developed European equity markets across multiple countries and industries. Firm-level emissions data are retrieved from Refinitiv and include Scope 1, Scope 2, and Scope 3 emissions, measured in logarithmic form. Macroeconomic variables are captured using the Harmonized Index of Consumer Prices (HICP) for the Euro Area, distinguishing between energy inflation and core inflation. The use of these two inflation measures allows the analysis to assess whether the interaction between emissions and inflation varies depending on the source of price pressures and whether energy-related inflation shocks play a particularly important role.

Using panel regressions of monthly stock returns on emissions, inflation measures, and interaction terms, the study evaluates whether firms with higher carbon emissions experience different return dynamics when inflation increases. The empirical specification follows the methodology of the reference paper and includes both firm fixed effects and industry-time fixed effects to account for unobserved heterogeneity and time-varying industry conditions. By applying this methodology to European data, the thesis evaluates whether the inflation-carbon premium relationship documented in the United States also holds in a different institutional environment characterized by stronger climate policies and higher awareness of environmental risks.

The results show that the interaction between emissions and energy inflation is generally negative once firm fixed effects are included, suggesting that carbon-intensive firms tend to experience lower stock returns when energy prices rise. In contrast, the relationship between emissions and core inflation appears weaker and less consistent. The robustness tests, including the addition of sales growth and return on equity as control variables, confirm the stability of the main findings. In addition, examining the interaction between inflation and carbon emissions is particularly relevant in the current macroeconomic environment. The sample period analyzed in this thesis includes several episodes of substantial energy price volatility, most notably the sharp increase in energy prices following the post-COVID economic recovery and the energy crisis associated with the war in Ukraine. These developments generated significant cost pressures across many European industries and highlighted the economic vulnerability of energy-intensive sectors. By studying how these macroeconomic shocks interact with firms' carbon emissions, this thesis provides additional insight into how climate transition risks may be reflected in financial markets during periods of heightened energy price uncertainty.

Overall, the analysis highlights the importance of energy-driven inflation in shaping the return performance of carbon-intensive firms in Europe and contributes to the broader literature on the pricing of climate-related risks in financial markets.

2. Literature Review

The Capital Asset Pricing Model (CAPM) of *Sharpe (1964)* and *Lintner (1965)* provides the foundation of modern asset pricing theory. Building on *Markowitz's (1959)* mean-variance portfolio framework, the CAPM shows that risk-averse investors choose portfolios based on expected return and variance. Sharpe and Lintner add two key assumptions: first, that investors share homogeneous expectations about asset returns; second, that borrowing and lending occur freely at a common risk-free rate. Under these assumptions, all investors hold the same tangency portfolio of risky assets, the value-weighted market portfolio, and expected returns are determined by the risk-free rate plus a premium proportional to market beta.

Empirical tests of the CAPM reveal limitations. Unrestricted borrowing and lending is unrealistic, and when short-selling or risk-free borrowing is constrained, the market portfolio is not typically efficient, and the relation between expected return and beta breaks down. Early cross-sectional and time-series tests *(Fama and MacBeth, 1973; Gibbons, 1982; Stambaugh, 1982)* show that market betas explain some variation in returns, but the Sharpe-Lintner CAPM prediction that the risk premium equals the expected market return minus the risk-free rate is consistently rejected. *Roll (1977)* further highlights that testing the CAPM is complicated because the true market portfolio is unobservable; tests therefore rely on proxies rather than the theoretical market portfolio itself.

Extensions of the CAPM, such as *Merton's (1973)* Intertemporal CAPM (ICAPM), address its limitations by incorporating multiple state variables. Unlike CAPM investors, ICAPM investors care not only about end-of-period wealth but also about future investment and consumption opportunities. They therefore consider how portfolio returns covary with variables such as labor income, consumer prices, and investment opportunities. Optimal portfolios are "multifactor efficient," maximizing expected returns given variances and covariances with these state variables. *Fama (1996)* shows that under market-clearing conditions, expected returns depend on multiple betas, generalizing the CAPM.

Empirical implementations often follow the logic of *Fama and French (1993, 1995),* who argue that characteristics such as size and book-to-market equity proxy for exposure to unidentified state variables that produce undiversifiable risks. *Carhart (1997)* further adds momentum as a factor, capturing patterns not explained by market, size, or value factors. Taking together, these multifactor models show that multiple sources of systematic risk matter beyond market beta.

Financial theory and empirical evidence suggest that asset prices respond to macroeconomic shocks, including inflation (*Chen, Roll, and Ross, 1986).* Expected inflation affects nominal cash flows and interest rates, while unanticipated inflation can systematically alter real cash flows and valuations. Changes in expected real production further affect current real cash flows. When standard risk-premium measures do not capture uncertainty in industrial production, innovations in economic activity influence stock returns through cash-flow effects. This literature establishes that inflation is a key macroeconomic factor relevant for asset pricing and motivates its inclusion when studying carbon-intensive firms exposed to energy price changes.

Beyond traditional financial variables, evidence shows that non-financial factors influence valuation and risk. *Hong and Yogo (2012)* demonstrate that commodity market movements predict returns in multiple asset classes, reflecting underreaction to economic news. Similarly, ESG factors and corporate social responsibility affect asset prices. *Heinkel, Kraus, and Zechner (2001)* show that exclusionary investment strategies reduce risk-sharing opportunities and lower polluting firms' stock prices. *Pedersen, Fitzgibbons, and Pomorski (2021)* formalize the ESG-efficient frontier, highlighting the complexities of incorporating ESG constraints into portfolio construction. *Zerbib (2019)* shows that green bonds earn a yield differential relative to conventional bonds, reflecting pro-environmental preferences. Together, these studies suggest that both risk-based and preference-based channels operate in climate-aware finance.

Energy price shocks represent a channel through which macroeconomic and climate risks interact. *Kilian (2008)* shows that firm-level exposure to real energy price shocks is generally smaller than crude oil price movements and that the macroeconomic effects of these shocks have weakened since the late 1980s. Different types of energy shocks produce heterogeneous effects on output, inflation, and stock returns. This distinction is crucial for understanding how energy-driven inflation may interact with the valuation of carbon-intensive firms.

Building on the previous literature, recent research documents that carbon risk is priced in equity markets. *Bolton and Kacperczyk (2021)* estimate the relationship between returns and lagged carbon emissions for U.S. companies, controlling for firm characteristics and industry-time fixed effects. They find that higher-emitting firms earn a carbon premium. Bolton and Kacperczyk (2022) extend this analysis globally, showing that carbon risk affects expected returns across countries. In Europe, despite high awareness of climate issues, firms with higher emissions are classified among the worst performers per firm-level emissions but still exhibit a positive and significant carbon premium. *Bolton, Halem, and Kacperczyk (2022*) document a widespread price-earnings discount linked to corporate carbon emissions for both European and U.S. companies. Other studies confirm these patterns: *Aswani, Raghunandan, and Rajgopal (2023)* find a positive relation between the natural logarithm of unscaled emissions and stock returns, while *Hsu, Li, and Tsou (2023)* document a "pollution premium" using long-short portfolios based on toxic emission intensity.

This literature demonstrates that carbon transition risk has a measurable effect on asset prices, but until recently, the interaction with macroeconomic variables such as inflation remained largely unexplored. *Bolton, Kacperczyk, and Wang (2024)* address this gap in the U.S., showing that energy price inflation amplifies the carbon premium for brown firms. Their results suggest that the mechanism is primarily risk-based, rather than reflecting investor preferences, and the effect is distinct from general monetary shocks or supply-driven energy price changes.

Despite these insights, the question remains whether the same relationship holds in Europe. European markets differ from the U.S. in several important ways: they operate under stronger climate policies, maintain a well-developed carbon market through the EU ETS, and have higher investor awareness of climate risk. Moreover, European firms may face varying levels of exposure to energy and core inflation, given the region's energy mix, regulation, and market integration. These features could cause the inflation-carbon premium relationship to differ from that observed in the U.S. evidence.

This thesis replicates *Bolton, Kacperczyk, and Wang (2024)* for European listed companies, explicitly considering the role of energy and core inflation in driving the carbon premium. By applying the same methodology to Europe, it evaluates whether the U.S. findings generalize to a different institutional and regulatory environment. In doing so, it contributes to three strands of the literature simultaneously: the asset-pricing implications of carbon-transition risk, the interaction between macroeconomic inflation and firm-level risk, and the understanding of European carbon pricing. This replication is not merely a mechanical exercise; it provides a meaningful extension that highlights how institutional and market differences shape the pricing of climate-related risk.

3. Data

3.1 Stock Returns and Control Variables

The sample of listed firms used to represent Europe is the *STOXX Europe 600 Index (STOXX600),* a broad measure of the European equity market. With a fixed number of 600 constituents, the index provides extensive and diversified coverage across 17 countries and 11 industries within Europe's developed economies, representing nearly 90% of the underlying investable market. It includes mid- and small-cap securities, thereby capturing their historical premium returns. The sample period spans from 01/01/2016 to 31/12/2024, resulting in a total of 64,800 observations in the main sample.

A potential limitation relates to the construction of the STOXX Europe 600 sample, as using a static list of index constituents rather than historical membership may introduce survivorship bias by excluding firms that exited the index during the sample period.

Table B reports summary statistics for stock returns and the firm characteristics used as control variables. The dependent variable in the panel regressions is the monthly stock return, $RET_{i,t}$, retrieved from Refinitiv and defined as the monthly return of the primary share of stock i in month t. The analysis focuses exclusively on securities classified as common or ordinary shares. Consistent with the paper being replicated and standard practice in asset pricing studies, observations for firms with stock prices below $1 are excluded.

1) $RET_{i,t} = \frac{Price_{i,t} - Price_{i,t-1}}{Price_{i,t-1}}$

To calculate returns, I follow the methodology used in the reference paper by applying a -30% delisting return. Over the sample period, the average monthly stock return is 0.854%, with a standard deviation of 8.380%.

The control variables used in the panel regressions are defined as follows:

i. *LOGSIZEi,t*: The natural logarithm (in thousand EUR) of firm i's market capitalization at the end of month t. Market capitalization is computed as the number of shares outstanding multiplied by the stock price.

ii. *LOGMBi,t:* The natural logarithm of the price-to-book ratio. Book equity is calculated as total assets minus total liabilities; preferred stock is then subtracted to obtain book value of equity. The market value of equity is computed as the stock price at time t multiplied by the number of common shares outstanding. The price-to-book ratio is the market value of equity divided by the book value of equity, and the logarithm is then taken.

iii. *LEVERAGEi,t:* Book leverage, defined as total debt divided by total assets.

iv. *MOMi,*t: Return momentum, measured as the buy-and-hold return over the most recent 12 months for stock i, up to and including month $t-1$.

v. *INVEST/A*: The ratio of capital expenditures to the book value of total assets.

vi. *LOGPPE:* The natural logarithm (in thousand EUR) of property, plant, and equipment, net of accumulated depreciation, retrieved from DataStream.

vii. VOLAT: The standard deviation of monthly stock returns over the preceding 12 months.

viii. *AGE*: The number of years the firm has been in operation as of year t, transformed as $1/(1+$ firm age), following the methodology of the replicated paper.

To mitigate the impact of outliers and to be consistent with the replicated study, LEVERAGE, MOM, INVEST/A, and VOLAT are winsorized at the 2.5% level using Python.

3.2 Carbon Emissions

Greenhouse gas emissions are typically categorized into three scopes according to the Greenhouse Gas Protocol, which distinguishes emissions based on their source within a firm's activities. Scope 1 emissions are direct emissions from sources owned or controlled by the firm, such as fuel combustion in company facilities or vehicles. Scope 2 emissions are indirect emissions from the production of purchased energy consumed by the firm, particularly electricity, heating, or cooling. Scope 3 emissions include all other indirect emissions that occur along the firm's value chain. These emissions arise both upstream and downstream of the firm's operations, for example, through purchased goods and services, transportation, product use, or waste disposal. Because Scope 3 emissions depend on activities outside the firm's direct control, they are typically more difficult to measure and are reported less consistently across firms.

Table A reports carbon emissions, measured as the natural logarithm of total Scope 1, Scope 2, and Scope 3 (upstream and downstream) emissions. Total greenhouse gas emissions are reported in metric tons of CO_2 equivalent and are available on Refinitiv at annual frequency. Scope 1 (code: ENERDP747) and Scope 2 (code: ENERDP751) data cover the period 2015–2024. Scope 3 data replicate the paper's time series starting in 2017-2024: upstream (code: ENERDP374), downstream (code: ENERDP371), and total (code: ENERDP377).

The dataset emissions are available starting in 2015, whereas the original paper begins in 2005. The relatively short time period available for emissions data in Europe limits the ability to study longer-term dynamics in the relationship between carbon exposure and asset prices. The sample period begins in 2016 due to data availability constraints, which prevent a direct replication of the longer time horizon used in the original U.S. study. As climate disclosure standards continue to improve and emissions datasets expand, future research will be able to examine longer time periods and explore whether the interaction between carbon risk and macroeconomic conditions evolves over time.

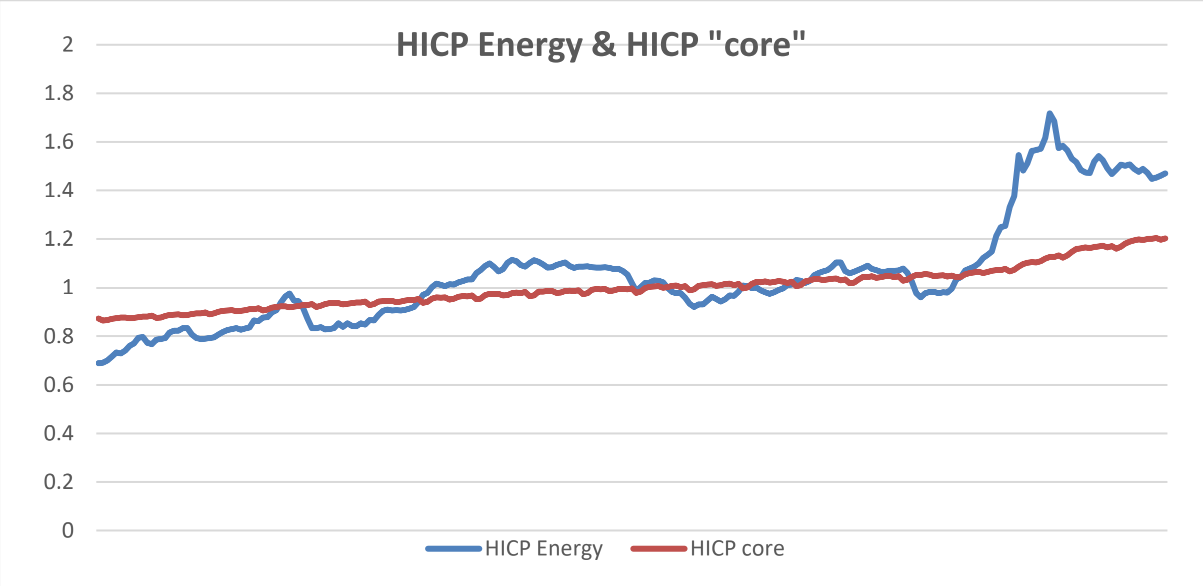
3.3 Macroeconomic Variables

To replicate the U.S. Energy CPI, I use the Harmonized Index of Consumer Prices (HICP) for Energy for the Euro Area (19 countries), retrieved from FRED. The index is monthly and expressed with a base year of 2015 = 100. The series is divided into 100 for scaling purposes.

To replicate the Core CPI, I use the HICP overall index excluding energy, food, alcohol, and tobacco for the Euro Area (19 countries), retrieved from FRED. The index is also monthly, and the series is divided by 100 for scaling purposes.

A limitation of this approach is that the macroeconomic variables are measured at the Euro Area level, whereas the STOXX Europe 600 Index includes firms from European countries, not all of which are part of the Euro Area. Therefore, the inflation measures may not perfectly capture country-specific price dynamics for firms headquartered outside the Euro Area. This mismatch between the geographic coverage of the macroeconomic variables and the equity sample should be considered when interpreting the results.

Figure 1: HICP Energy & HICP Core



As shown in Figure 1, energy inflation exhibits substantially greater volatility than core inflation over the sample period. In particular, energy prices rose sharply after 2021, reflecting the European energy crisis associated with the war in Ukraine. These larger fluctuations suggest that energy-driven inflation shocks may have a stronger impact on firms' cost structures, especially for carbon-intensive firms that rely more heavily on energy inputs. This higher volatility also reflects the strong sensitivity of energy markets to geopolitical events, supply disruptions, and fluctuations in global demand. Because energy prices affect production, transportation, and heating costs across a wide range of industries, these shocks can quickly propagate through the broader economy. Consequently, periods of sharp energy price increases may have particularly important implications for firms whose production processes rely heavily on energy inputs.

An important characteristic of the European energy system is its strong reliance on imported energy resources. Energy available in the European Union consists of both domestic production and imports from non-EU countries, meaning that energy supply conditions in Europe are strongly influenced by international energy markets. According to the European Commission, in 2023, the EU produced roughly 42% of the energy it consumed, while approximately 58% was imported (Eurostat, 2025). Oil and petroleum products accounted for the largest share of these imports, at about 65% of total imported energy, followed by natural gas at roughly 25%. The structure of the European energy mix further illustrates this dependence on fossil fuels, with petroleum products representing about 37.7% of gross available energy, natural gas 20.4%, renewable energy 19.5%, nuclear energy 11.8%, and solid fossil fuels 10.6%. Energy consumption is also uneven across sectors of the European economy. Transport represents the largest share of final energy consumption, accounting for around 32%, followed by households (26%), industry (25%), commercial and public services (14%), and agriculture and related activities (3%) (Eurostat, 2025). These structural characteristics imply that fluctuations in global energy prices can have significant economic consequences for European firms, particularly those operating in energy-intensive industries. As a result, energy price shocks and energy-driven inflation may play an important role in shaping the economic environment in which European firms operate.

3.4 Missing data

Table C reports the number of missing observations for the variables used in the analysis. The highest proportion of missing data is observed for Scope 3 emissions, particularly downstream Scope 3 emissions (54.65%) and upstream Scope 3 emissions (38.54%), reflecting the more recent and less consistent disclosure of these emissions across firms. Among the remaining variables, the price-to-book ratio (LOGMB) presents 22.44% missing observations, while Scope 1 emissions have 17.15% missing values. Measures such as volatility and momentum indicate that around 13% of observations are missing. In contrast, most firm-level control variables display relatively low levels of missing data, generally below 6%. Observations with missing values are excluded from the regressions to ensure consistency in the empirical analysis. However, the high proportion of missing observations for Scope 3 emissions may introduce sample selection concerns, as firms that disclose these emissions may systematically differ from those that do not. In particular, firms reporting Scope 3 emissions are often larger or more subject to sustainability reporting requirements, which may limit the representativeness of the resulting subsample.

4. Methodology

Following Bolton, Kacperczyk, and Wang (2024), I estimate a panel regression of monthly stock returns on carbon emissions, inflation measures, and their interaction terms, including firm and industry-time fixed effects. Standard errors are double-clustered at the firm and year levels.

First, I construct the panel dataset using the variables described in the previous section. Monthly stock returns are measured at time t. Firm-level control variables are lagged by one period and included at time $t-1$. Emissions variables are also lagged by one year. For example, emissions measured in 2018 are used to explain 2019 monthly stock returns.

To start the analysis, a minimal model is estimated in which stock returns are regressed only on emissions, where $RET_{i,t}$denotes the stock return of the firm i in month t. TOT Emissions is a generic term referring, in turn, to the firm's Scope 1 emissions (LOGS1), Scope 2 emissions (LOGS2), and upstream (LOGS3) and downstream (LOGS3D) Scope 3 emissions, all measured in logarithmic form.

Consistent with the replicated study, standard errors are double-clustered at the firm and year levels. This approach accounts for cross-firm correlation in the residuals and for the fact that several control variables and emissions are measured annually.

2) $RET_{i,t} = \alpha + \beta_1 \text{TOTEmissions}_{i,t-1} + \mu j, t + \varepsilon_{i,t}$

The next specification introduces both industry-time and firm fixed effects. The model includes industry-time fixed effects $(\mu_{j,t})$ and firm fixed effects (μ_i). Industries are classified using the TRBC4 industry codes obtained from Refinitiv. Industry-time fixed effects control for unobserved factors that vary across industries and over time, such as aggregate and sector-specific macroeconomic shocks. Their inclusion is particularly important in transition-risk analyses, given the substantial heterogeneity in emissions across industries, as documented by Bolton and Kacperczyk (2023).

Firm fixed effects control for time-invariant firm characteristics that may be correlated with emissions. This is particularly relevant because carbon emissions tend to be highly persistent over time and are strongly linked to firms' underlying production technologies and industry structures. Without firm fixed effects, the estimated relationship between emissions and stock returns could partly reflect permanent cross-sectional differences between firms rather than the effect of emissions themselves. By controlling for these time-invariant characteristics, the specification isolates the impact of changes in macroeconomic conditions interacting with firms' carbon exposure.

3) $RET_{i,t} = \alpha + \beta_1 \text{TOTEmissions}_{i,t-1} + \mu_{j,t} + \mu_i + \varepsilon_{i,t}$

The regression results show a negative relationship between carbon emissions and stock returns when only industry-time fixed effects are included. The coefficients for all emissions measures are negative and statistically significant, firms with higher emissions tend to have lower returns relative to other firms within the same industry-time group. However, once firm fixed effects are added, the magnitude of the coefficients decreases substantially, and most estimates lose statistical significance. This indicates that the relationship is largely driven by cross-sectional differences between firms rather than changes in emissions within the same firm over time.

Table D: Baseline regression

Emissions	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	53688	-0.112	-3.051	0.000985
Scope1	Yes	2016	53688	-0.070	-1.296	0.000062
Scope2	No	2016	57180	-0.126	-3.816	0.001159
Scope2	Yes	2016	57180	-0.124	-1.861	0.000165
Scope3 up	No	2017	35052	-0.087	-2.561	0.000469
Scope3 up	Yes	2017	35052	-0.046	-0.986	0.000039
Scope3 down	No	2017	26064	-0.133	-3.841	0.000995
Scope3 down	Yes	2017	26064	0.0142	0.256	0.000003

Next, both emissions and inflation variables are centered to facilitate the interpretation of the level effects in the presence of interaction terms. Interaction terms between lagged emissions and centered inflation measures are then constructed in Python. Specifically, the following interaction variables are created:

- $\text{LOGS1}_{i,t-1} \times \text{HICP}_t^{Energy}$
- $\text{LOGS1}_{i,t-1} \times \text{HICP}_t^{Core}$
- $\text{LOGS2}_{i,t-1} \times \text{HICP}_t^{Energy}$
- $\text{LOGS2}_{i,t-1} \times \text{HICP}_t^{Core}$
- $\text{LOGS3U}_{i,t-1} \times \text{HICP}_t^{Energy}$
- $\text{LOGS3U}_{i,t-1} \times \text{HICP}_t^{Core}$

- $\text{LOGS3D}_{i,t-1} \times \text{HICP}_t^{Energy}$
- $\text{LOGS3D}_{i,t-1} \times \text{HICP}_t^{Core}$

The main regression model, replicating the specification of the reference paper, is constructed as follows:

4) $RET_{i,t} = \alpha + \beta_1 \text{TOTEmissions}_{i,t-1} + \beta_2 \text{Inflation}_t + \beta_3 (\text{TOTEmissions}_{i,t-1} \times \text{Inflation}_t) + \gamma \text{Controls}_{i,t-1} + \mu_{j,t} + \varepsilon_{i,t}$

The next specification adds industry-time and firm fixed effects:

5) $RET_{i,t} = \alpha + \beta_1 \text{TOTEmissions}_{i,t-1} + \beta_2 \text{Inflation}_t + \beta_3 (\text{TOTEmissions}_{i,t-1} \times \text{Inflation}_t) + \gamma \text{Controls}_{i,t-1} + \mu_{j,t} + \mu_i + \varepsilon_{i,t}$

Table E presents the results of panel regressions examining the interaction between firms' carbon emissions and energy inflation (Energy HICP) and the effects of this interaction on stock returns. When only industry-time fixed effects are included, the interaction coefficients are generally small and statistically insignificant, suggesting limited evidence that carbon intensity affects industry-level stock returns in response to energy inflation.

Table E: HICP Energy

Scope	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37255	0.122	1.347	0.003
Scope1	Yes	2016	37255	-0.136	-1.262	0.008
Scope2	No	2016	40013	-0.058	-0.631	0.003
Scope2	Yes	2016	40013	-0.233	-2.166	0.008
Scope3 up	No	2017	22669	-0.097	-0.709	0.003
Scope3 up	Yes	2017	22669	-0.345	-2.191	0.006
Scope3 down	No	2017	17571	-0.080	-0.495	0.004
Scope3 down	Yes	2017	17571	-0.400	-2.190	0.007

However, once firm fixed effects are introduced, the coefficients become more negative and statistically significant for several emissions measures. In particular, the interaction terms for

Scope 2 emissions (β = -0.233, t = -2.17) and Scope 3 emissions (both upstream and downstream) are negative and significant. These results indicate that firms with higher carbon emissions tend to experience lower stock returns when energy prices increase. Overall, the findings suggest that carbon-intensive firms are more negatively affected by rising energy costs, consistent with greater exposure to energy price shocks and transition-related risks.

Table F reports the results of the interaction between firms' carbon emissions and core inflation (Core HICP) on stock returns. When only industry-time fixed effects are included, the interaction coefficients are generally small and statistically insignificant, providing limited evidence that carbon intensity influences industry-level stock returns in response to core inflation. However, after introducing firm fixed effects, the coefficients become more negative. In particular, the interaction for Scope 2 emissions (β = -0.865, t = -2.19) is negative and statistically significant, while the estimates for Scope 3 emissions are also negative but only marginally significant. These results suggest that firms with higher carbon emissions tend to experience lower stock returns when core inflation increases, although the effect appears less consistent than for energy inflation. Overall, the findings indicate that carbon-intensive firms may be more vulnerable to broader inflationary pressures, but the relationship is weaker than that with energy-driven inflation shocks.

Table F: HICP Core

Scope	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37255	0.621	1.879	0.003
Scope1	Yes	2016	37255	-0.395	-1.003	0.008
Scope2	No	2016	40013	-0.068	-0.199	0.003
Scope2	Yes	2016	40013	-0.865	-2.192	0.008
Scope3 up	No	2017	22669	0.348	0.693	0.003
Scope3 up	Yes	2017	22669	-0.639	-1.092	0.006
Scope3 down	No	2017	17571	0.174	0.291	0.004
Scope3 down	Yes	2017	17571	-1.248	-1.836	0.007

Comparing the two specifications, the relationship between carbon emissions and stock returns appears stronger when inflation is driven by energy prices rather than by core inflation. In the Energy HICP regressions, the interaction coefficients become negative and statistically significant for several emissions measures once firm fixed effects are included, particularly for

Scope 2 and Scope 3 emissions. In contrast, the Core HICP results show weaker and less consistent effects, with only the Scope 2 interaction remaining statistically significant. This suggests that the negative response of carbon-intensive firms is more closely linked to energy-related inflation shocks.

5. Development of findings

The baseline results indicate that carbon-intensive firms tend to experience lower stock returns during periods of rising inflation, particularly when inflation is driven by increases in energy prices. The interaction between emissions and Energy HICP becomes negative and statistically significant for several emissions measures once firm fixed effects are included, suggesting that firms with higher emissions are more adversely affected by energy-related inflation shocks. By contrast, the relationship between emissions and Core HICP appears weaker and less consistent, with statistically significant effects observed mainly for Scope 2 emissions. Previous research highlights that indirect emissions, particularly Scope 2 and Scope 3, often account for a substantial share of firms' total carbon footprint and may therefore reflect broader exposure to carbon-related risks (Bolton & Kacperczyk, 2021). Taken together, these results suggest that energy-driven inflation plays a more important role in explaining differences in stock return performance across firms with varying levels of carbon emissions.

One possible interpretation of these findings is that firms with higher emissions are more exposed to energy price shocks. Carbon-intensive production processes typically rely more heavily on energy inputs such as electricity, fuel, or industrial heat. Consequently, increases in energy prices may generate disproportionately higher operating costs for these firms compared with less carbon-intensive firms. If firms are unable to fully pass these higher costs on to consumers, profit margins may decline, which can negatively affect investor expectations regarding future profitability. Moreover, rising energy prices may increase the perceived importance of transition risk, as markets anticipate stronger regulatory pressure and higher compliance costs for carbon-intensive industries. These mechanisms may help explain why firms with higher emissions tend to experience weaker stock performance when energy inflation increases.

To further assess the robustness of these findings, the next section presents additional empirical tests.

5.1 Sales Growth

As an additional robustness test, the baseline specification is extended to include sales growth as a control variable. Sales growth captures changes in firms' operating performance that may be correlated with both emissions' intensity and stock returns and therefore helps ensure that the estimated effects are not driven by differences in firms' growth opportunities. The results remain largely unchanged compared to the baseline specification. ***Table G*** shows that once firm fixed effects are included, the interaction coefficients between emissions and energy inflation remain negative and statistically significant for Scope 2 and Scope 3 emissions. This indicates that the negative relationship between carbon intensity and stock returns during periods of rising energy prices is robust to controlling for firms' sales growth. Overall, ***Table H*** shows that the findings continue to suggest that more carbon-intensive firms experience relatively lower returns when energy inflation increases. Core inflation remains negative and statistically significant for Scope 2 emissions ($\beta = -0.868$, $t = -2.20$). The coefficients for Scope 3 emissions are also negative but not statistically significant. Overall, these results suggest that the relationship between carbon intensity and stock returns during periods of higher inflation is robust to controlling for firms' sales growth, although the effects remain weaker and less consistent than those observed for energy inflation.

5.2 ROE

As an additional robustness test, corporate profitability is included in the baseline specification by controlling for return on equity (ROE), retrieved from Refinitiv and winsorized at the 2.5% level to mitigate the influence of extreme values. This variable captures firms' operating profitability and allows us to assess whether the relationship between emissions exposure and stock returns during periods of rising energy prices is driven by differences in corporate performance. The results remain broadly consistent with the baseline specification. Once firm fixed effects are included, the interaction between emissions and Energy HICP (***Table I***) remains negative and statistically significant for Scope 2 ($\beta = -0.229$, $t = -2.12$) and Scope 3 emissions ($\beta = -0.342$ for upstream and $\beta = -0.384$ for downstream). These findings suggest that the negative response of carbon-intensive firms to energy price shocks is robust to control for corporate profitability. Overall, the results continue to indicate that firms with higher emissions tend to experience relatively lower stock returns when energy prices increase.

A further robust test examines whether the results are sensitive to controlling for corporate profitability when inflation is measured using Core HICP (***Table L***). The results remain broadly consistent with the baseline findings. Once firm fixed effects are included, the interaction between emissions and core inflation remains negative and statistically significant for Scope 2 emissions (β = -0.879, t = -2.22). The coefficients for Scope 3 emissions are also negative, though not statistically significant at conventional levels. Overall, these findings confirm that the negative relationship between carbon intensity and stock returns is robust to controlling for corporate profitability, although the effects remain weaker and less consistent when core inflation is used rather than energy prices.

5.3 Firm Size

To examine whether the relationship between carbon emissions, inflation, and stock returns differs across firms of different sizes, an additional heterogeneity analysis is conducted. Firm size is measured using the natural logarithm of market capitalization (LOGSIZE), defined as the logarithm of the firm's market value of equity at the end of the month t. The sample is divided into two groups based on the median value of LOGSIZE, which equals 15.863 in the sample. Firms with a value of LOGSIZE above the median are classified as large firms, while firms below the median are classified as small firms. This split results in 34,662 observations for small firms and 30,138 observations for large firms. Estimating the model separately for each subsample allows the analysis to investigate whether the interaction between carbon emissions and inflation differs depending on firm size.

For each size group, the baseline regression specification is estimated separately. The empirical model follows the methodology of Bolton, Kacperczyk, and Wang (2024) and is specified as:

$$6)\ RET_{i,t} = \beta_0 + \beta_1\, TOTEmissions_{i,t-1} + \beta_2\,(TOTEmissions_{i,t-1} \times Inflation_t)+) \\ + \gamma\text{Controls}_{i,t-1} + \mu_{j,t} + \mu_i + \varepsilon_{i,t}$$

where $RET_{i,t}$represents the monthly stock return of the firm i in month t, expressed in percentage terms. $TOTEmissions_{i,t-1}$ denotes the firm's lagged carbon emissions, measured alternatively using Scope 1, Scope 2, Scope 3 upstream, and Scope 3 downstream emissions. $Inflation_t$represents the inflation measure, captured by either the Energy HICP or the Core HICP. The interaction term between emissions and inflation captures whether firms with higher carbon emissions experience different return dynamics during periods of rising inflation.

The vector $\gamma\text{Controls}_{i,t-1}$ includes the same set of lagged firm-level control variables used in the baseline regressions: firm size, market-to-book ratio, leverage, momentum, investment intensity, property, plant and equipment, return volatility, and firm age. Firm fixed effects (μ_i) and industry-time fixed effects ($\mu_{j,t}$) are included to control for unobserved firm characteristics and time-varying industry-level shocks. Standard errors are double-clustered at the firm and year levels to account for both cross-sectional and temporal correlation in the error terms.

Because inflation is common across firms within a given month, its standalone effect is absorbed by the industry-time fixed effects. As a result, the main coefficient of interest in this specification is the interaction term between emissions and inflation, which captures how the relationship between carbon emissions and stock returns changes during periods of higher inflation.

The results of the firm-size heterogeneity analysis indicate that the interaction between carbon emissions and inflation differs between small and large firms. In general, the interaction coefficients tend to be more negative for small firms than for large firms, suggesting that smaller firms may be more sensitive to inflation-driven carbon risk.

In ***Table M*** using Energy HICP, the interaction coefficients for large firms are generally small and statistically insignificant. By contrast, for small firms, the coefficients are consistently negative and, in some cases, statistically significant. The strongest result emerges in the specification using Scope 3 upstream emissions, where the interaction coefficient is negative and statistically significant for small firms. This suggests that firms with higher upstream carbon emissions tend to experience lower stock returns during periods of rising energy inflation, particularly among smaller firms.

The results in ***Table N*** for Core HICP display a similar pattern. While most interaction coefficients for large firms remain statistically insignificant, several of the coefficients for small firms are negative and statistically significant. In particular, the interaction terms associated with Scope 1 and Scope 2 emissions show negative and significant estimates for the small-firm subsample. These findings suggest that smaller firms with higher carbon emissions may experience relatively weaker stock performance during periods of rising inflation.

Overall, the results indicate that the negative relationship between carbon emissions and stock returns during periods of rising inflation appears to be more pronounced among smaller firms. One possible explanation is that smaller firms may have fewer financial resources to hedge energy price risks or to invest in technologies that reduce carbon intensity. As a result, increases in energy prices or broader inflationary pressures may have a stronger impact on their operating costs and profitability. In contrast, larger firms may benefit from greater diversification, stronger market power, or better access to capital markets, which could mitigate the impact of inflation-related shocks.

Although the results are not uniformly significant across all emissions measures, the overall pattern suggests that firm size plays an important role in shaping the relationship between carbon emissions, inflation, and stock returns. These findings provide additional evidence that firms' exposure to inflation-driven carbon risk may vary across market segments.

5.4 Extreme Emissions Analysis (Top 25% vs Bottom 25%)

To further examine whether the relationship between carbon emissions, inflation, and stock returns differs across firms with different levels of carbon exposure, an additional heterogeneity analysis is conducted based on the distribution of emissions. Firms are ranked each year according to their emissions levels, and the sample is divided into quartiles (Top 25% vs Bottom 25%). Firms in the top quartile are classified as high-emission firms, while firms in the bottom quartile are classified as low-emission firms. Firms in the middle two quartiles are excluded in order to focus on the most pronounced differences in carbon exposure.

The empirical specification follows the baseline model used in the main analysis. The following panel regression is estimated separately for the two subsamples:

$$7)\ RET_{i,t} = \beta_0 + \beta_1\, TOTEmissions_{i,t-1} + \beta_2\,(TOTEmissions_{i,t-1} \times Inflation_t) + \gamma \text{Controls}_{i,t-1} + \mu_{j,t} + \mu_i + \varepsilon_{i,t}$$

where $R_{i,t}$ represents the monthly stock return of firm i in month t, $Emissions_{i,t-1}$ denotes lagged emissions, and $Inflation_t$corresponds to either Energy HICP or Core HICP. The vector $yControls_{i,t-1}$includes the same firm-level control variables used in the baseline regressions, and firm fixed effects are included to control for time-invariant firm characteristics.

The regression results indicate that the interaction between emissions and inflation differs substantially across the two groups. For low-emission firms, the interaction between emissions and energy inflation is positive and statistically significant ***Table O***. For example, the interaction coefficient for Scope 1 emissions is β = 0.853 (t = 4.64) and for Scope 2 emissions β = 0.833 (t = 4.67). In contrast, the interaction with core inflation is generally weaker and less consistent, with statistical significance observed primarily for Scope 2 emissions among high-emission firms ***(Table P)***.

For high-emission firms, the results display a markedly different pattern. The interaction between emissions and energy inflation becomes negative and statistically significant. In particular, the coefficients for Scope 1 and Scope 2 emissions are β = −0.630 (t = −4.03) and β = −0.995 (t = −4.88), respectively. Similarly, the interaction between emissions and core inflation becomes negative and statistically significant for Scope 2 emissions (β = −1.869, t = −2.56).

Overall, these results suggest that the negative relationship between carbon emissions and stock returns during periods of rising inflation is concentrated among firms with the highest levels of carbon exposure. Highly carbon-intensive firms appear more vulnerable to rising energy prices, likely reflecting their greater reliance on energy-intensive production processes and heightened exposure to transition-related risks.

5.5 COVID-19 and the war in Ukraine

An important characteristic of the European energy system is its strong reliance on imported energy resources. Energy available in the European Union consists of both domestic production and imports from non-EU countries, meaning that energy supply conditions in Europe are strongly influenced by international energy markets. These structural characteristics imply that fluctuations in global energy prices can have significant economic consequences for European firms, particularly those operating in energy-intensive industries. As a result, energy price shocks and energy-driven inflation may play an important role in shaping the economic environment in which European firms operate.

To assess whether major macroeconomic shocks affect the relationship between carbon emissions and stock returns, the sample is partially divided into three subperiods: the pre-COVID period (up to May 2020), the COVID recovery period (June 2020 to January 2022), and the period associated with the war in Ukraine (February 2022 to December 2022). Estimating the model separately across these subperiods allows the analysis to examine whether the interaction between carbon emissions and energy inflation varies across different macroeconomic environments characterized by distinct energy market conditions.

In the pre-COVID period, ***Table Q***, the results indicate a generally negative relationship between emissions and stock returns when energy prices increase. In particular, Scope 2 emissions display a statistically significant negative coefficient once firm fixed effects are included (β = −1.465, t = −2.053). The coefficients for Scope 1 emissions are also negative (β = −0.606, t = −0.914), although not statistically significant. For Scope 3 emissions, the estimates are likewise negative, with the upstream measure showing a coefficient of β = −1.849 (t = −1.407). These results suggest that, even prior to the pandemic, firms with higher carbon emissions tended to experience weaker stock performance when energy prices increased.

During the COVID recovery period, ***Table R***, the relationship weakens, and in some cases changes sign. For example, the coefficient for Scope 2 emissions becomes positive once firm fixed effects are included (β = 0.577, t = 1.098). The most notable result appears for Scope 3 upstream emissions, which show a positive and statistically significant coefficient (β = 1.918, t = 2.829). This reversal may reflect the unusual macroeconomic conditions during the post-pandemic recovery, when strong demand, supply-chain disruptions, and fiscal stimulus altered production patterns and temporarily weakened the negative relationship between carbon exposure and stock returns.

In contrast, during the period associated with the war in Ukraine, ***Table S***, the coefficients again became strongly negative across most emissions measures. For example, Scope 1 emissions show a coefficient of β = −1.479 (t = −1.832), while Scope 2 emissions display a negative coefficient of β = −1.245 (t = −1.542). The strongest effect appears for Scope 3 upstream emissions, which remain negative and statistically significant (β = −2.409, t = −2.185). These results coincide with the sharp increase in European energy prices following disruptions to energy supply and highlight the vulnerability of carbon-intensive firms to energy-price shocks.

Overall, the subperiod analysis suggests that the relationship between carbon emissions and stock returns is sensitive to macroeconomic conditions. While the negative relationship between emissions and stock returns weakens during the COVID recovery period, it becomes stronger again during the energy crisis associated with the war in Ukraine. This pattern reinforces the thesis's broader finding that energy-driven inflation plays an important role in shaping the performance of carbon-intensive firms.

5.6 Interpretation of Differences Between European and U.S. Evidence

The results of this thesis differ in several important respects from those reported in Bolton, Kacperczyk, and Wang (2024). In their study of U.S. listed firms, the authors document that energy price inflation amplifies the carbon premium, meaning that firms with higher carbon emissions earn higher realized returns when energy prices rise. In particular, they find that the interaction between emissions and energy inflation is positive and statistically significant, indicating that investors demand greater compensation for holding stocks of carbon-intensive firms when energy price risk increases. By contrast, the empirical results obtained in this thesis suggest a different relationship in the European context. Once firm fixed effects are included, the interaction coefficients between emissions and energy inflation (Energy HICP) become negative and statistically significant for several emissions measures, particularly Scope 2 and Scope 3 emissions. This implies that, in the European sample, firms with higher carbon emissions tend to experience lower stock returns during periods of rising energy prices. While both studies find that energy-related inflation plays a more important role than core inflation in explaining the relationship between emissions and returns, the direction of the effect differs. One possible explanation for this divergence lies in differences in the institutional and market environments. European firms operate under stronger climate policies and carbon-pricing mechanisms, which may increase the cost pressures faced by carbon-intensive firms when energy prices rise. In addition, differences in sample composition, data availability for emissions, and the use of Euro Area inflation measures may contribute to the variation in results.

Overall, the findings of this thesis suggest that, in the European context, rising energy prices may negatively affect the performance of carbon-intensive firms rather than increasing the carbon premium. This highlights the importance of regional institutional and macroeconomic conditions in shaping how carbon-transition risk is reflected in asset prices. One possible explanation for the difference between the results obtained in this study and those documented for the United States lies in the institutional and regulatory environment of European markets.

In particular, European firms operate within a policy framework characterized by stronger climate regulation and explicit carbon pricing mechanisms. The European Union Emissions Trading System (EU ETS) plays a central role in this framework by placing a price on carbon emissions through a cap-and-trade mechanism. According to the European Central Bank (ECB), the EU ETS has helped reduce greenhouse gas emissions while generating long-term benefits for the environment, the European economy, and energy independence. Empirical evidence suggests that carbon pricing mechanisms, such as the EU ETS, encourage firms to undertake green investments to reduce the carbon intensity of their production processes. Compared with alternative policy instruments, carbon pricing is widely regarded as an efficient mechanism for incentivizing the adoption of low-carbon technologies and reducing emissions.

The ECB also reports that sectors with high carbon intensity are particularly affected by carbon price shocks. In particular, industries such as construction, transportation, and manufacturing experience the largest investment adjustments when carbon prices increase. As these sectors are often characterized by high energy consumption and relatively high levels of emissions, increases in energy prices may translate into stronger cost pressures for firms operating in these industries.

Furthermore, existing research shows that a carbon premium is present in European equity markets both before and after the Paris Climate Agreement. Bolton and Kacperczyk (2022) find evidence of a significant carbon premium in Europe, although the premium associated with Scope 1 emissions becomes statistically insignificant after the Paris Agreement. Importantly, their results suggest no significant change in the magnitude of the carbon premium in Europe around the Paris event. Taken together, these findings indicate that institutional factors, such as carbon pricing policies and regulatory frameworks, may influence how energy price shocks interact with firms' carbon exposure in European financial markets.

6. Conclusion

This thesis investigates the relationship between carbon emissions, inflation, and stock returns in European equity markets. Replicating the methodology of Bolton, Kacperczyk, and Wang (2024), the analysis examines whether inflation amplifies the pricing of carbon-transition risk for firms included in the STOXX Europe 600 Index. Using firm-level emissions data retrieved from Refinitiv and macroeconomic inflation measures based on the Harmonized Index of Consumer Prices (HICP) for the Euro Area, the study evaluates how the interaction between emissions and inflation affects the return performance of carbon-intensive firms. An implication of these findings relates to the interpretation of the carbon premium in different macroeconomic environments. While previous evidence, particularly for the U.S., suggests that higher emissions are associated with higher expected returns, the results obtained in this thesis indicate that this relationship may reverse under specific conditions. In the European context, periods of rising energy prices appear to amplify the costs associated with carbon-intensive production rather than increase compensation for risk. This suggests that the pricing of carbon risk is not stable over time but instead depends on the interaction between firm characteristics and prevailing macroeconomic conditions.

Moreover, the baseline results indicate that the interaction between emissions and energy inflation plays an important role in explaining stock returns. When only industry-time fixed effects are included, the estimated interaction coefficients are generally small and statistically insignificant. However, once firm fixed effects are introduced, the coefficients become more negative and statistically significant for several emissions measures. In particular, the interaction terms for Scope 2 and Scope 3 emissions suggest that firms with higher carbon emissions tend to experience lower stock returns when energy prices increase. These findings indicate that carbon-intensive firms appear to be more adversely affected by increases in energy prices, consistent with their greater exposure to energy costs and production processes that rely heavily on energy inputs.

In contrast, the results for core inflation are weaker and less consistent. Although the interaction between emissions and Core HICP becomes negative when firm fixed effects are included, the effects are statistically significant mainly for Scope 2 emissions. This difference suggests that the relationship between carbon emissions and stock returns is more strongly linked to energy-driven inflation shocks than to broader inflation dynamics. The greater volatility observed in energy prices during the sample period, particularly during the European energy crisis following the war in Ukraine, may explain why energy inflation plays a more prominent role in shaping the performance of carbon-intensive firms.

Several robustness tests confirm the stability of the main findings. The inclusion of additional firm-level controls, such as sales growth and return on equity, does not materially alter the results. In both cases, the interaction between emissions and energy inflation remains negative and statistically significant for Scope 2 and Scope 3 emissions once firm fixed effects are included. These results indicate that the relationship between carbon intensity and stock returns during periods of rising energy prices is not driven by differences in firms' growth opportunities or corporate profitability.

Additional analyses further support the interpretation that inflation-driven carbon risk affects firms differently depending on their characteristics. The firm-size analysis shows that smaller firms tend to exhibit stronger negative interactions between emissions and inflation, suggesting that they may be more vulnerable to rising energy costs. Similarly, the analysis comparing firms with extremely high and low emissions indicates that the negative relationship between emissions and stock returns during periods of rising inflation is concentrated among firms with the highest levels of carbon exposure.

The results also highlight the importance of macroeconomic conditions in shaping the pricing of carbon risk. When the sample is divided into different macroeconomic sub-periods, the relationship between emissions and energy inflation becomes particularly pronounced during periods of strong energy price shocks, such as the energy crisis associated with the war in Ukraine. These findings suggest that the interaction between carbon exposure and inflation may become more relevant when energy markets experience substantial volatility.

Overall, the results of this thesis suggest that carbon emissions interact with inflation in shaping the return performance of European firms, particularly when inflation is driven by energy prices. Carbon-intensive firms appear more vulnerable to rising energy prices, which may reflect their greater exposure to energy costs and transition-related risks. By replicating the framework of Bolton, Kacperczyk, and Wang (2024) in the European context, this study contributes to the growing literature on the pricing of climate-related risks in financial markets and highlights the importance of macroeconomic conditions in understanding how carbon exposure is reflected in asset prices. The findings also suggest that institutional and regulatory differences across regions may influence how carbon risk is priced in financial markets, reinforcing the importance of accounting for regional characteristics when studying the interaction between climate risk and macroeconomic variables. These findings also have implications for investors and policymakers concerned with the financial consequences of climate transition risks. As energy markets remain volatile and climate policies continue to evolve, firms with high carbon exposure may face increasing pressure to adapt their production processes and investment strategies. Understanding how macroeconomic conditions interact with carbon intensity may therefore become increasingly important for asset pricing and risk management.

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Data sources

STOXX 600 STOXX® Europe 600 - STOXX

Harmonized Index of Consumer Prices:

https://fred.stlouisfed.org/series/ENRGY0EZ19M086NEST

Harmonized Index of Consumer Prices: Overall Index Excluding Energy, Food, Alcohol, and Tobacco: https://fred.stlouisfed.org/series/00XEFDEZ19M086NEST

Appendix

Summary statistics

Table A: Macro-economic variables

Macro-economic Variables	*Mean*	*p50*	*SD*	*Min*	*Max*
Hicp energy	1.193	1.071	0.237	0.920	1.717
Hicp core	1.073	1.047	0.062	0.988	1.204
Scope 1	9.619	9.794	2.373	0.198	13.801
Scope 2	10.325	10.539	2.116	0.343	13.814
Scope 3 up	10.993	11.374	2.052	1.386	13.806
Scope 3 down	11.452	11.865	1.864	2.302	13.812

Table B: Control Variables

Control variables	*Mean*	*p50*	*SD*	*Min*	*Max*
ret	0.854	0.183	8.380	-29.984	125.133
logsize	15.953	15.863	1.201	8.687	19.891
logmb	0.500	0.495	1.118	-5.521	7.494
leverage	0.249	0.240	0.152	0.008	0.592
mom	0.108	0.077	0.283	-0.386	0.873
invest/a	0.029	0.022	0.030	-0.304	0.443
logppe	13.932	14.075	2.221	0.647	19.227
volat	0.077	0.072	0.028	0.035	0.153
age	0.051	0.037	0.179	-	-
salesgr	0.084	0.059	0.203	-0.346	0.742
ROE	0.146	0.132	0.144	-0.212	0.581

Table C: Missing Data

Variable	*Non-missing Obs*	*Missing Obs*	*Missing (%)*
Scope 3 down	29388	35412	54.65
Scope 3 up	39828	24972	38.54
logmb	50260	14540	22.44
Scope 1	53688	11112	17.15
volat	56378	8422	13.00

mom	56378	8422	13.00
Scope 2	57180	7620	11.76
logsize	60276	4524	6.98
Invest/a	61416	3384	5.22
leverage	62081	2719	4.20
ROE	62096	2704	4.17
salesgr	62544	2256	3.48
logppe	62769	2031	3.13
age	64020	780	1.20
industry	64584	216	0.33

Regressions

Table G: Sales growth – HICP Energy

HICP Energy	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37243	0.124	1.364	0.003
Scope1	Yes	2016	37243	-0.136	-1.261	0.008
Scope2	No	2016	40001	-0.058	-0.624	0.003
Scope2	Yes	2016	40001	-0.233	-2.169	0.008
Scope3 up	No	2017	22657	-0.097	-0.714	0.003
Scope3 up	Yes	2017	22657	-0.346	-2.198	0.006
Scope3 down	No	2017	17559	-0.071	-0.438	0.004
Scope3 down	Yes	2017	17559	-0.402	-2.203	0.007

Table H: Sales growth – HICP Core

HICP Core	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37243	0.623	1.884	0.003
Scope1	Yes	2016	37243	-0.394	-1.000	0.008
Scope2	No	2016	40001	-0.066	-0.194	0.003
Scope2	Yes	2016	40001	-0.868	-2.198	0.008
Scope3 up	No	2017	22657	0.347	0.690	0.003
Scope3 up	Yes	2017	22657	-0.629	-1.075	0.006
Scope3 down	No	2017	17559	0.212	0.354	0.004

Scope3 down	Yes	2017	17559	-1.253	-1.843	0.007

Tables I: ROE – HICP Energy

HICP Energy	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37102	0.120	1.317	0.003
Scope1	Yes	2016	37102	-0.138	-1.274	0.008
Scope2	No	2016	39895	-0.058	-0.624	0.003
Scope2	Yes	2016	39895	-0.229	-2.121	0.008
Scope3 up	No	2017	22573	-0.095	-0.695	0.003
Scope3 up	Yes	2017	22573	-0.342	-2.167	0.006
Scope3 down	No	2017	17497	-0.055	-0.337	0.004
Scope3 down	Yes	2017	17497	-0.384	-2.070	0.007

Tables L: ROE – HICP Core

HICP Core	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	37102	0.599	1.808	0.003
Scope1	Yes	2016	37102	-0.425	-1.078	0.008
Scope2	No	2016	39895	-0.083	-0.242	0.003
Scope2	Yes	2016	39895	-0.879	-2.224	0.008
Scope3 up	No	2017	22573	0.345	0.688	0.003
Scope3 up	Yes	2017	22573	-0.635	-1.086	0.006
Scope3 down	No	2017	17497	0.183	0.304	0.004
Scope3 down	Yes	2017	17497	-1.275	-1.863	0.007

Table M: SIZE – HICP Energy

HICP Energy	*size*	*start*	*N*	*β*	*T-stat*	*R2*
Scope1	Large	2016	18284	0.035	0.192	0.006
Scope1	Small	2016	18971	-0.166	-0.994	0.005
Scope2	Large	2016	19794	0.135	0.705	0.007
Scope2	Small	2016	20219	-0.376	-1.525	0.005

Scope3 down	Large	2017	7443	-0.337	-1.750	0.006
Scope3 down	Small	2017	10128	-0.540	-1.244	0.004
Scope3 up	Large	2017	9571	-0.103	-0.350	0.004
Scope3 up	Small	2017	13098	-0.597	-2.283	0.005

Table N: SIZE – HICP Core

HICP Core	*size*	*start*	*N*	*β*	*T-stat*	*R2*
Scope1	Large	2016	18284	0.334	0.482	0.006
Scope1	Small	2016	18971	-0.855	-2.143	0.005
Scope2	Large	2016	19794	0.487	0.659	0.007
Scope2	Small	2016	20219	-1.483	-2.024	0.005
Scope3 down	Large	2017	7443	-1.494	-1.206	0.006
Scope3 down	Small	2017	10128	-2.145	-1.458	0.004
Scope3 up	Large	2017	9571	-0.230	-0.199	0.004
Scope3 up	Small	2017	13098	-1.650	-1.213	0.005

Table O: Extreme Emissions – HICP Energy

HICP Energy	*Group*	*N*	*β*	*T-stat*	*R2*
Scope 1	Low emitters	7801	0.853	4.644	0.031
Scope 1	High emitters	10519	-0.630	-4.033	0.026
Scope 2	Low emitters	8686	0.833	4.666	0.030
Scope 2	High emitters	11366	-0.995	-4.882	0.024
Scope 3 upstream	Low emitters	4920	0.331	1.446	0.028
Scope 3 upstream	High emitters	6324	-1.361	-4.128	0.030

Scope 3 downstream	Low emitters	4385	0.409	1.277	0.028
Scope 3 downstream	High emitters	4199	-2.141	-3.662	0.038

Table P: Extreme Emissions – HICP Core

HICP Core	*Group*	*N*	*β*	*T-stat*	*R2*
Scope 1	Low emitters	7801	0.347	0.563	0.028
Scope 1	High emitters	10519	-0.676	-1.230	0.024
Scope 2	Low emitters	8686	0.239	0.397	0.027
Scope 2	High emitters	11366	-1.869	-2.555	0.022
Scope 3 upstream	Low emitters	4920	-0.772	-0.969	0.028
Scope 3 upstream	High emitters	6324	-1.766	-1.516	0.028
Scope 3 downstream	Low emitters	4385	-0.834	-0.724	0.028
Scope 3 downstream	High emitters	4199	-2.358	-1.187	0.034

Table Q: Pre Covid

Pre covid	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	18207	-0.734	-1.313	0.004
Scope1	Yes	2016	18207	-0.606	-0.914	0.007
Scope2	No	2016	19591	-1.441	-2.387	0.004
Scope2	Yes	2016	19591	-1.465	-2.053	0.008
Scope3 up	No	2017	10324	-0.362	-0.297	0.005

Scope3 up	Yes	2017	10324	-1.849	-1.407	0.009
Scope3 down	No	2017	7270	0.145	0.093	0.006
Scope3 down	Yes	2017	7270	-0.764	-0.453	0.010

Table R: Post Covid

Post covid	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	6281	-0.455	-0.862	0.010
Scope1	Yes	2016	6281	-0.154	-0.280	0.004
Scope2	No	2016	6790	-0.128	-0.249	0.008
Scope2	Yes	2016	6790	0.577	1.098	0.004
Scope3 up	No	2017	4360	1.342	2.043	0.009
Scope3 up	Yes	2017	4360	1.918	2.829	0.008
Scope3 down	No	2017	3494	0.488	0.608	0.006
Scope3 down	Yes	2017	3494	1.114	1.243	0.006

Table S: Ukraine war

Ukraine War	*Firm FE*	*Start*	*N*	*β*	*T-stat*	*R2*
Scope1	No	2016	3765	-1.681	-2.033	0.008
Scope1	Yes	2016	3765	-1.479	-1.832	0.009
Scope2	No	2016	4028	-1.620	-2.007	0.008
Scope2	Yes	2016	4028	-1.245	-1.542	0.007
Scope3 up	No	2017	2417	-3.292	-2.942	0.014
Scope3 up	Yes	2017	2417	-2.409	-2.185	0.012
Scope3 down	No	2017	2041	-1.007	-0.884	0.018
Scope3 down	Yes	2017	2041	-0.977	-0.843	0.010